

## High-Rate Clarification for the Treatment of Wet Weather Flows

### Overview

Many municipalities experience high wastewater flows during wet weather due to inflow and infiltration into sewer systems. All the problems caused by wet weather can not be alleviated by sewer system repair; additional treatment must be provided.

Traditional approaches have been used in expanding wastewater treatment capacity such as adding primary and secondary treatment units or building on-line or off-line flow equalization basins. Costs increase significantly when considering the limited time these additional facilities are used. Typically, peak wet weather events occur less than 20 times during the year and last for relatively short periods of time. Therefore, alternative wet weather treatment methods are needed that (1) do not require large amounts of capital funds, (2) can be brought on line quickly, and (3) are easy to operate and maintain.

High-rate clarification (HRC) offers advantages for treating wet weather flows at less cost than conventional biological treatment systems. HRC

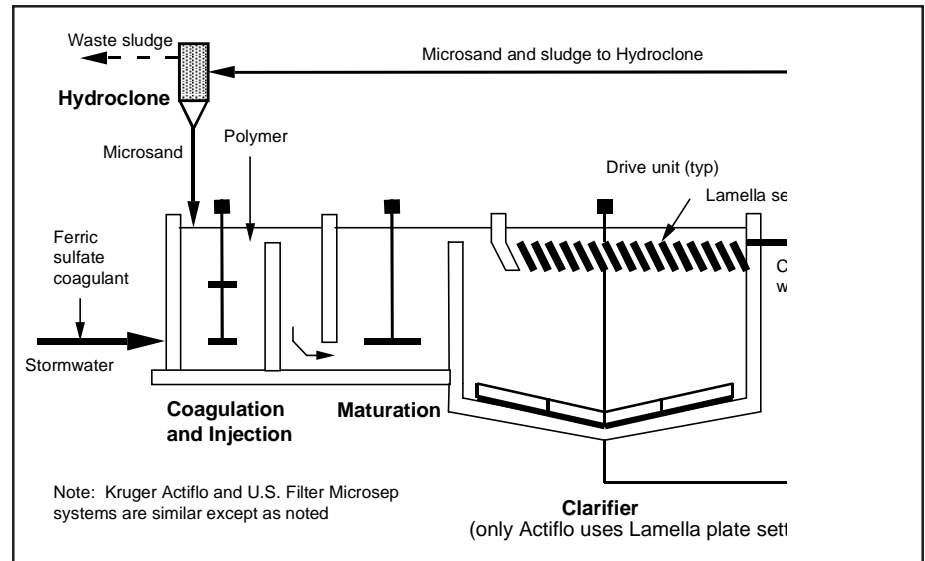


Figure 1. Ballasted Flocculation Process

employs physical/chemical treatment and utilizes special flocculation and sedimentation systems to achieve rapid settling. Advantages of HRC are: (1) units are compact and thus reduce space requirements, (2) start-up times are rapid (usually less than 30 minutes) to achieve peak efficiency, and (3) a highly clarified effluent is produced.

HRC plants are being constructed in Europe and Canada for treating combined sewer overflows (CSOs) and are being studied in the United States for similar applications. This *TechCommentary* will review the technology and describe a case study in Fort Worth, Texas where side-by-side testing of four HRC systems was done.

Table 1. Summary of Process Features

Process	Description	Features
Actiflo	Microsand ballasted flocculation and lamella clarification	Microsand provides nuclei for floc formation Floc is dense and settles rapidly Lamella clarification provides high rate settling in a small tank volume
Microsep	Microsand ballasted flocculation/solids contact and clarification	Microsand provides nuclei for floc formation Floc is dense and settles rapidly Mixing, flocculation, and high-rate settling are done in a single vessel
Lamella plate settler	Chemical addition, multi-stage flocculation, and lamella clarification	Three-stage flocculation enhances floc formation Lamella clarification provides high rate settling in a small tank volume
Densadeg	Two-stage flocculation with chemically-conditioned recycled sludge followed by lamella clarification	Settled sludge solids are recycled to accelerate floc formation Dense floc is formed that settles rapidly Lamella clarification provides high rate settling in a small tank volume

## Process Description

HRC systems that can be used for wet weather treatment are:

- Actiflo® Process (Kruger)
- Microsep® Ballasted Floc Reactor™ (U.S. Filter)
- Lamella Plate Clarification Process (Parkson)
- Densadeg® 4D Process (Infilco-Degremont)

These processes are summarized in Table 1 and are described in more detail in the following paragraphs.

### Ballasted Flocculation

The Kruger and U.S. Filter treatment systems are very similar in concept. The process is termed “ballasted flocculation,” which utilizes physical/chemical treatment with a ballast (sand) to form dense microfloc particles. Because these particles are formed around sand, they settle rapidly. Figure 1 illustrates the features of this process.

The two systems have similar elements—a mixing zone, a maturation zone, and a settling zone—but they are configured differently. Kruger’s Actiflo uses serial compartments to perform the process functions while U.S. Filter’s Microsep combines them in a single vessel. Actiflo also utilizes lamella plate settling, whereas Microsep uses conventional gravity clarification.

Typically, screened wastewater is introduced to the ballasted flocculation reactor where a chemical coagulant (typically an iron salt) is injected to destabilize the solids. The wastewater then enters a mixing zone where microsand and polymer are injected to maximize the efficiency of flocculation and enhance settling of suspended solids.

In the mixing zone, the polymer acts as a bonding agent for adhering the destabilized solids to the microsand.

The maturation zone follows and is used to keep the solids in suspension while microfloc continues to develop and grow. Once developed, the microfloc settles rapidly to the bottom of the clarifier. Sand and floc particles removed from the clarified water are pumped to a cyclone separator (hydroclone) for sand removal. Cleaned sand is returned to the injection tank, and solids from the hydroclone are sent to the biosolids handling system for disposal.

### Lamella Plate Clarification

The Parkson process uses chemical addition with three-stage flocculation followed by a lamella plate clarifier. A typical section of the process is shown on Figure 2. Coagulant and polymer are injected into the influent wastewater prior to entering the flocculation zone. When chemically conditioned wastewater passes through the flocculation zone, the energy gradient decreases as the wastewater proceeds from the first to the third stage. The chemically conditioned/flocculated wastewater then passes to the lamella clarifier for solids separation. The clarifier underflow can be recycled to the influent of the process and/or sent to a thickening tank and the solids disposal system.

### Densadeg Process

The Infilco-Degremont Densadeg 4D process, shown on Figure 3, uses chemically conditioned sludge to form microfloc particles with the incoming wastewater. The influent wastewater enters an air-mixing zone where grit separation occurs and coagulant (ferric sulfate) is injected. After mixing, the

wastewater flows into the first stage of a two-stage flocculation tank where polymer is added together with chemically conditioned, recirculated sludge. Recirculated sludge accelerates the flocculation process and ensures the formation of dense, homogeneous floc particles. In the second stage of flocculation, grease and scum begin separating and are removed. Effluent from the flocculation tank enters a pre-settling zone followed by a lamella plate settler. Most of the suspended flocculated solids are separated directly in the pre-settling zone; the residual flocculated particles are removed in the lamella settler. A portion of the settled solids is recirculated, and the remainder is sent to the sludge processing and disposal system.

## Case Study

The City of Fort Worth, Texas experiences wet weather flows in excess of 255 million gallons per day at its Village Creek wastewater treatment plant. The City obtained a permit to internally divert peak flows of primary influent to an enhanced high-rate clarification process. In order to evaluate the effectiveness of high-rate clarification under site-specific conditions, the city hired the firm of Camp Dresser & McKee Inc. to pilot test the four high-rate processes discussed above.

### Pilot Plant Program

The four pilot units were positioned around one of the treatment plant’s existing primary clarifiers. Raw wastewater was diluted with plant effluent to simulate wet weather conditions. Tests were also conducted on undiluted wastewater.

The pilot-testing program consisted of two-phases: process optimization and

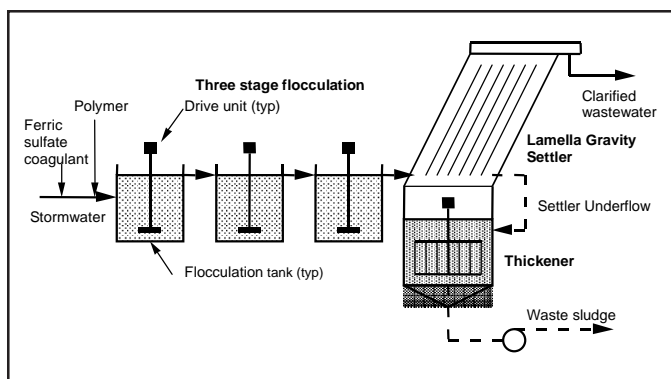


Figure 2. Parkson Lamella Plate Clarification Process

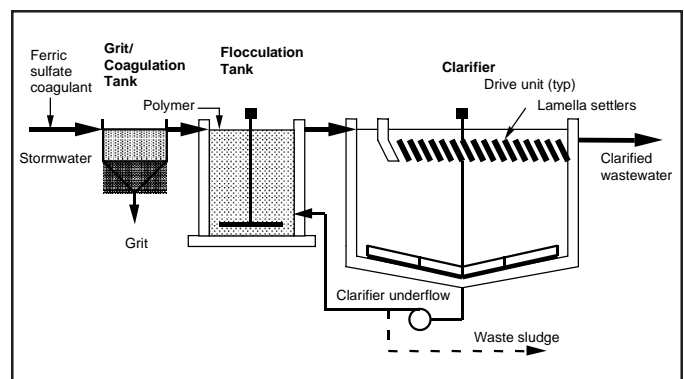


Figure 3. Densadeg 4D Process

then demonstration. In the optimization phase, the testing protocol was implemented, chemical dosages and operating parameters were established, and equipment was checked and fine-tuned. In the demonstration phase, each pilot unit was operated over a range of overflow rates recommended by the equipment manufacturer to reach maximum treatment efficiency (see Table 2). The units were tested on a side-by-side basis on screened and degrittied wastewater. Ferric sulfate and anionic polymer were added as coagulating chemicals. Influent and effluent water quality parameters that were measured included total suspended solids (TSS), organic matter—5-day biochemical oxygen demand (BOD), total phosphorus, and total Kjeldahl nitrogen (TKN). Sludge samples were tested for solids concentration, metals content, and volatile solids content.

## Test Results

### Simulated Stormwater Conditions.

Testing was conducted initially to determine the time required for the units to achieve peak efficiency. Because operating units have to be brought on line quickly under peak wet weather conditions, the readiness to perform is important in process selection. The Actiflo, Microsep, and Densadeg 4D units reached peak operating efficiency within the first 20 minutes of operation. The Parkson Lamella unit did not reach peak efficiency until approximately 120 minutes of operation due to its longer retention time. Although the Lamella process was slower to reach its peak efficiency, it still performed effectively after 20 minutes of operation; its performance ranged from 85 to 90 percent of peak efficiency at all overflow rates.

Average removal efficiencies were determined for each water quality parameter and for each test unit under simulated wet weather conditions. The removal efficiencies for BOD, TSS, TKN, and phosphorus are shown on Figures 4, 5, 6, and 7 for the range of overflow rates described in Table 2. With a few exceptions, TSS and phosphorus removals ranged between 70 and 90 percent and were the most consistent (see Figures 5 and 7). TKN removal was the lowest; ranging from 20 to over 30 percent.

**Table 2. Operating Range of Overflow Rates for Pilot Units**

Treatment Device	Range of Overflow Rates gpm/ft <sup>2</sup> (m <sup>3</sup> /m <sup>2</sup> •d)		
	Low	Medium	High
Parkson Lamella Clarifier	15 (880)	20 (1,173)	30 (1,760)
U.S. Filter Microsep	20 (1,173)	30 (1,760)	40 (2,347)
Degremont Densadeg 4D	40 (2,347)	50 (2,934)	60 (3,520)
Kruger Actiflo	50 (2,934)	60 (3,520)	70 (4,107)

Of the four water quality parameters tested, the greatest variability occurred in BOD removal (Figure 4). It is interesting to note that some units performed better under higher overflow rates, and others were better under lower.

### Raw Wastewater Testing.

Raw wastewater test results (shown on Figure 8) indicated the constituent removal rates were similar to the stormwater results. These tests indicate that HRC might also be applied where chemically-assisted primary treatment is being considered for augmenting the capacity of a wastewater treatment plant.

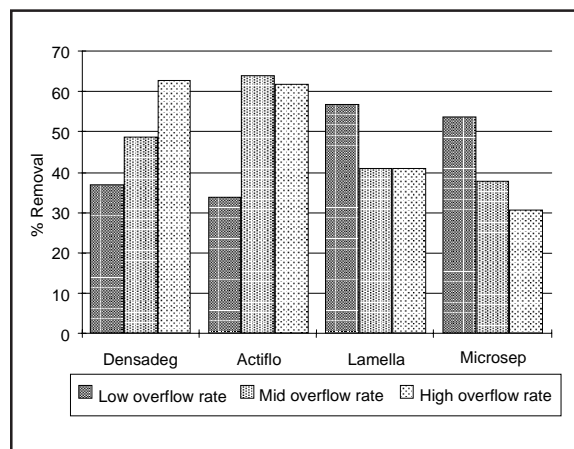
### Residual Sludge Characteristics.

In addition to analyzing each process unit's capabilities, characteristics of the residual sludge were also analyzed. Average values for solids concentration and ratios of volatile suspended solids (VSS) to total suspended solids (TSS) are reported in Table 3.

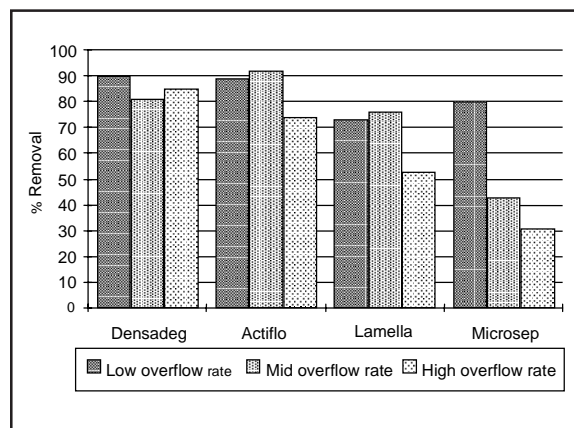
## Conclusions

From the pilot plant study, the following is concluded:

- High rate clarification is effective in treating wet weather flows. TSS removals on the order of 70 to 90 percent were achieved with some exceptions. Similar removals of phosphorus were also obtained.



**Figure 4. BOD Removal Efficiencies**



**Figure 5. Total Suspended Solids Removal Efficiencies**

- BOD removals ranged from 35 to 65 percent, depending on the process and overflow rate. Nitrogen removals were on the order of 20 to 30 percent.
- Because of differences in the individual processes, pilot testing is strongly recommended to determine performance and design parameters.
- In three of the four processes tested, the units reached peak operating performance within 20 minutes of operation, time sufficient to begin treatment of wet weather flows.

## Recommendations

- Depending on the process, recommended overflow rates ranged from 20 to 40 gpm/ft<sup>2</sup>. The highest overflow rate (40 gpm/ft<sup>2</sup>) was recommended for Actiflo and Densadeg.
- Recommended chemical/microsand dosages were 70 to 125 mg/L for ferric sulfate, 0.75 to 1.0 mg/L for anionic polymer, and 7 to 10 mg/L for microcarrier concentration.

## Summary

High rate clarification offers the following advantages in wastewater treatment:

- Because the process can operate at high overflow rates, the facilities are compact, which saves valuable real estate and reduces construction costs.
- HRC can be used for treating excess wet weather flows, thus reducing the hydraulic loads on secondary treatment facilities.
- Electrical loads are low when compared to conventional secondary treatment facilities.
- HRC can provide chemically-assisted primary treatment to relieve overloaded biological treatment systems. The units require significantly less space than conventional primary clarifiers.

- Depending on the process selected and the application, the clarifier underflow might not require additional thickening.

Disadvantages of high-rate clarification are:

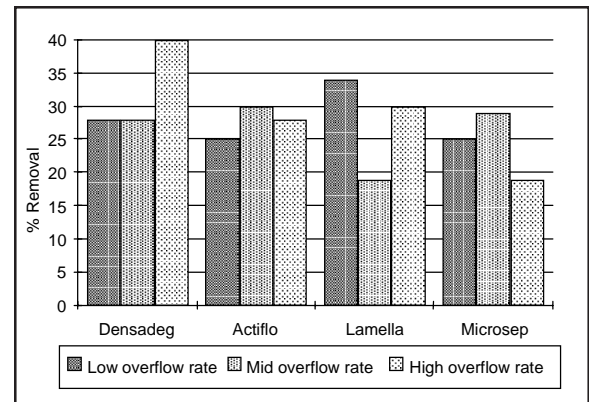
- There are only a few operating facilities in North America, principally in Canada. Most installations are in Europe.
- The processes are proprietary, which restricts bidding and limits the choices for future facilities.
- HRC facilities require chemical storage and handling; iron salts in particular are very corrosive and require special containment.

## Reference

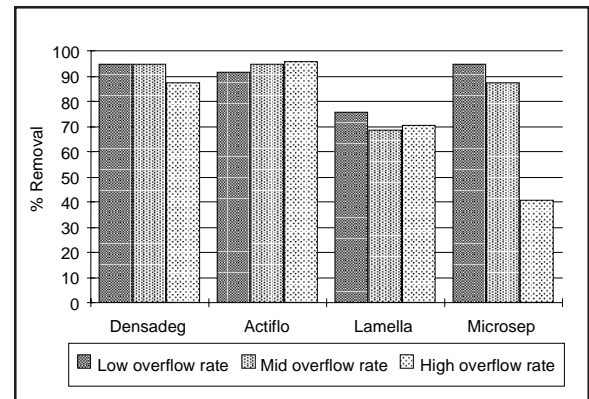
Camp Dresser & McKee: "Implementing Alternative Wet Weather Technology", Report to the City of Fort Worth, TX, 1999.

**Table 3. Pilot Plant Clarifier Underflow Characteristics**

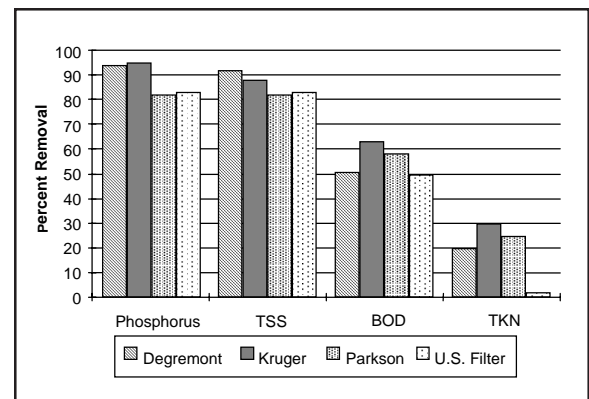
Treatment Device	Solids Concentration, %	VSS/TSS Ratio
Parkson Lamella Clarifier	2.91	0.61
U.S. Filter Microsep	0.38	0.54
Degremont Densadeg 4D	2.98	0.71
Kruger Actiflo	0.32	0.61



**Figure 6. TKN Removal Efficiencies**



**Figure 7. Phosphorus Efficiencies**



**Figure 8. Removal Efficiencies for Raw Wastewater**

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